

Q No. 7.5:-

$$P_b = 7\%$$

$$48.88$$

$$G_m = 2.24$$

$$G_b = 1.02$$

$$T_{ref} = 120^\circ F (49^\circ C)$$

$$P = 50$$

$$(25.5^\circ)$$

$$G_g = 2.61$$

$$|E| = ??$$

$$T = 74^\circ F$$

$$(23.33^\circ C)$$

$$t = 0.02 \text{ sec}$$

From Nomograph:

$$@ t = 0.02, \text{ temp. diff} = 25.5^\circ C$$

$$PI = ??$$

$$A = \frac{\log(50) - \log(800)}{25 - 49} = \frac{0.0501}{-0.627}$$

$$PI = \frac{200 - 500A}{1.5 + 50A} = -1.441$$

$$\text{Stiffness modulus of bitumen} = 2.0 \times 10^7 \text{ N/m}^2$$

$$V_b = 100 P_b G_m / G_b = (100 \times 0.07 \times 2.24) / 1.02 = 15.37$$

$$V_g = \frac{(1 - P_b) G_m \times 100}{G_g} = \frac{(1 - 0.07) \times 2.24 \times 100}{2.61} = 79.82\%$$

$$@ \text{stiffness mod. of bit.} = 2 \times 10^7 \text{ N/m}^2$$

$$V_b = 15.37\% \quad \& \quad V_g = 79.82\%$$

$$\text{stiffness modulus of mix} = 2 \times 10^3 \text{ N/m}^2$$

From eqn.:-

$$\beta_1 = \frac{10.82 - 1.342(100 - V_g)}{V_g + V_b} = \frac{10.82 - 1.342(100 - 79.82)}{(15.37 + 79.82)} = 10.53$$

$$\beta_2 = 8 + 0.00568 V_g + 0.0002135 V_g^2 = 8.838$$

$$\beta_3 = 0.6 \log \left(\frac{1.37 V_b^2 - 1}{1.33 V_b - 1} \right) = 0.732$$

$$\beta_4 = 0.7582 (\beta_1 - \beta_2) = 1.818$$

$$S_b = 10^8 \text{ N/m}^2 \Rightarrow \text{for } 5 \times 10^6 \text{ N/m}^2 < S_b < 10^9 \text{ N/m}^2$$

$$\log S_m = \frac{\beta_4 + \beta_3}{2} (\log S_b - 8) + \frac{\beta_4 - \beta_3}{2} |\log S_b - 8| + \beta_c$$

$$= \frac{(0.597 + 1.157)}{2} (\log 10^8 - 8) + \frac{0.597 - 1.157}{2} |\log 10^8 - 8| + 0.814$$

$$= \frac{(0.852)(0)}{1} + 0 + 0.814$$

$$S_m = \exp(0.814)$$

$$= 6.52 \times 10^9 \text{ N/m}^2$$

$$= (0.852)(-0.699) + (-0.305)(1) + 0.8991 + 0.814$$

$$\log S_m = 9.00526 \quad \log S_m = 9.30236$$

$$S_m = 10^{(9.00526)} \quad S_m = 2.006 \times 10^9 \text{ N/m}^2$$

$$S_m = 1.01 \times 10^9 \text{ N/m}^2$$

Almost equal values.

Quiz on 19.

→ Mechanistic approach:

Qno. 7.6:-

$P_{200} = 5\%$ Penetration of 75 at 77°F
 $|E^*| = ??$ @ 74°F $f = 8 \text{ Hz}$

Data from Qno. 7.5:-

$P_b = 7\%$ $G_m = 2.24$ $G_b = 1.02$ $T_{R\&P} = 120^\circ\text{F} (49^\circ\text{C})$
 $G_g = 2.61 \Rightarrow V_b = 15.37\%$ $V_g = 79.82\%$ $V_a = 4.81\%$

$$\begin{aligned} \text{Eqn. 7.28} \Rightarrow \lambda &= 29508.2 (P_{77})^{-2.1939} \\ &= 29508.2 (75)^{-2.1939} \\ \lambda &= 2.0849 \times 10^6 \text{ poise} \end{aligned}$$

Using eqn. 7.29:

$$\begin{aligned} \beta_5 &= 1.3 + 0.49825 \log f \\ &= 1.3 + 0.49825 \log(8) \\ \beta_5 &= 1.75 \end{aligned}$$

$$\beta_4 = 0.483 \quad V_b = 0.483 \left(\frac{15.37}{7.424} \right) = 3.381$$

$$\begin{aligned} \beta_3 &= 0.553833 + 0.028829 (5 \times 8^{-0.0703}) - 0.03476 (4.81) + \\ &\quad 0.070377 (2.0849 \times 10^6) + 0.931757 \times 8^{-0.02774} \\ &= 0.553833 + 0.1011587 - 0.1671956 + 0.146722 + 0.87953 \\ \beta_3 &= 1.514048685 \end{aligned}$$

$$\beta_2 = \beta_1^{1/2} T^{\beta_5} = (7.424)^{1/2} (74)^{1.75} = 5087.15$$

$$\begin{aligned} \beta_2 &= \beta_3 + 0.000005 \beta_2 - 0.00189 \beta_2 f^{-1.1} \\ &= \beta_3 + 0.02543575 - 0.9761967601 = 0.5632876753 \end{aligned}$$

$$1E^*1 = 100,000 \times 10^{31}$$

$$= 365.84 \times 10^3 = \underline{3.66 \times 10^5 \text{ psi}}$$

BOOK ANSWER = $3.8 \times 10^5 \text{ psi}$

Q NO. 7.7 :-

Given data:

$$\epsilon_t = 0.00015 \quad N_f = ??$$

Data from question #7.5:-

$$PI = 1.441$$

$$s_m = 2 \times 10^9 \text{ N/m}^2$$

$$V_b = 15.37\%$$

Using AI eqn. in

for const. stress test:-

Eqn/ 7.32:

$$0.00015 = [36.43 \times 1.441 - 1.82 (-1.441)(15.37) + 9.71 (15.37) - 24.04] \times 10^6 \left(\frac{2 \times 10^9}{5 \times 10^9} \right)^{-0.128} \left(\frac{N_f}{10^6} \right)^{-0.12}$$

$$0.00015 = (137.06) \times 10^6 (1.2925) \left(\frac{N_f}{10^6} \right)^{-0.12}$$

$\Rightarrow N_f =$

$$0.00015 = (137.06) \times 10^6 (1.2925) \left(\frac{N_f}{10^6} \right)^{-0.12}$$

$\Rightarrow N_f =$

Eqn/ 7.33 \Rightarrow

$$N_f = [0.0252 PI - 0.00126 PI (V_b) + 0.00673 V_b - 0.0167]^5 \epsilon_t^{-5} s_m^{-1.4}$$

$$N_f = \left[0.0252(-1.441) - 0.00126(-1.441)(15.37) + 0.00673 \times \right. \\ \left. 15.37 - 0.0167 \right]^5 (0.00015)^5 \times \left(\frac{2 \times 10^9}{6.9 \times 10^3} \right)^{-1.4}$$

$$N_f = 8.754 \times 10^5 \text{ repetitions} \quad (8.8 \times 10^8 \text{ Book answer})$$

For constant strain test.

Eqn. 7.35 \Rightarrow

$$N_f = \left[0.17PI - 0.0085PI(V_b) + 0.0154V_b - 0.112 \right]^5 \epsilon_c^{-5} \delta_m^{-1.8} \\ = \left[0.17(-1.441) - 0.0085(-1.441)(15.37) + 0.0154(15.37) \right. \\ \left. - 0.112 \right]^5 (0.00015)^5 \left(\frac{2 \times 10^9}{6.9 \times 10^3} \right)^{-1.8}$$

$$N_f = 8.04 \times 10^7 \text{ repetition} \quad (\text{Book answer: } 8.1 \times 10^7)$$

Using graph (Fig. 7.26) in

Values are verified from graph

Using $PI = -1.441$ (For B&K const. stress

$$V_b = 15.37$$

$\dot{\epsilon}$ strain)

$$\delta_m = 2 \times 10^9 \text{ N/m}^2$$

$$\dot{\epsilon} \quad \epsilon_c = 1.5 \times 10^{-4}$$

Qno. 7.8:-

Given that: $C_t = 0.00015$

$N_f = ??$

From Qno. 7.6 data req. is:

$$V_a = 4.81\%$$

$$V_b = 15.37\%$$

$$|E^*| = 3.8 \times 10^5 \text{ psi}$$

Eqn. 7.36 \Rightarrow

$$N_f = 0.00432 C_t^{-3.291} |E^*|^{-0.854}$$

Eqn. 7.37(a) \Rightarrow

$$C = 10^M$$

Eqn. 7.37(b) \Rightarrow

$$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69 \right)$$

$$= 4.84 \left(\frac{15.37}{4.81 + 15.37} - 0.69 \right)$$

$$M = \cancel{0.83291}^{(2)} 0.17271$$

$$\Rightarrow C = 10^M = \cancel{3.488}^{(2)} 1.48838$$

$$\Rightarrow N_f = 0.00432 (\cancel{3.488})^{1.4884} (0.00015)^{-3.291} (3.8 \times 10^5)^{-0.854}$$

$$N_f = 4.24 \times 10^5$$

(Book answer: 6.4×10^5)

Using eqn/.. 7.38:

$$N_f = 0.0796 E_t^{-3.231} |E^*|^{-0.854}$$

$$N_f = 5.25 \times 10^6$$